

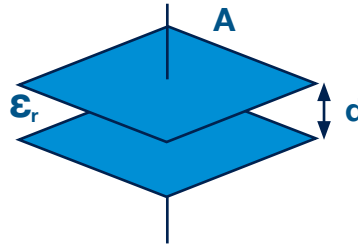
## CAPACITOR EQUATIONS AND UNITS

$$C = Q/V$$

Where Q is Charge and V is Voltage

$$C = \epsilon_0 \times \epsilon_r (A/d)$$

Where  $\epsilon_0$  is the permittivity of a vacuum  
 $\epsilon_r$  is the permittivity of the dielectric  
 A is the total area of the plates and d is the distance between them



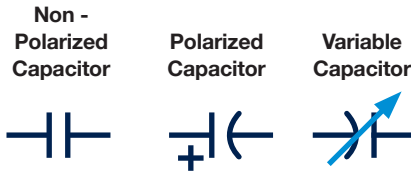
$$\text{Energy Stored} = 1/2 (C \times V^2)$$

The unit of capacitance is the Farad, symbol F.  
 Typical capacitor values range from 10 F down to 1 pF.

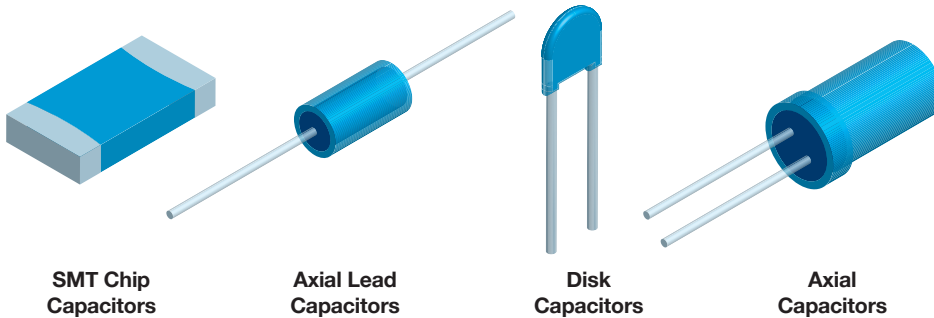
## KEY CAPACITOR TECHNOLOGIES

- Ceramic
- Electrolytic
- Film
- Multi layer ceramic capacitor (MLCC)
- Polymer
- Tantalum

## CAPACITOR TYPES & SYMBOLS

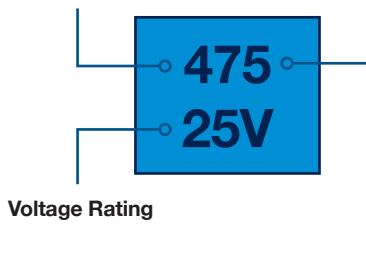


## CAPACITOR SIZES & FORMATS



## CAPACITOR MARKINGS

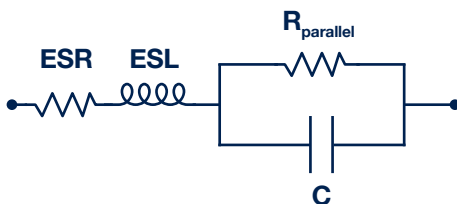
1st and 2nd digits indicate the capacitor value – in this example 47



3rd digit gives the multiplier, with 0 indicating tens of pF. See opposite table. In this example, 475 is 4.7  $\mu$ F.

## CAPACITOR EQUIVALENT CIRCUIT

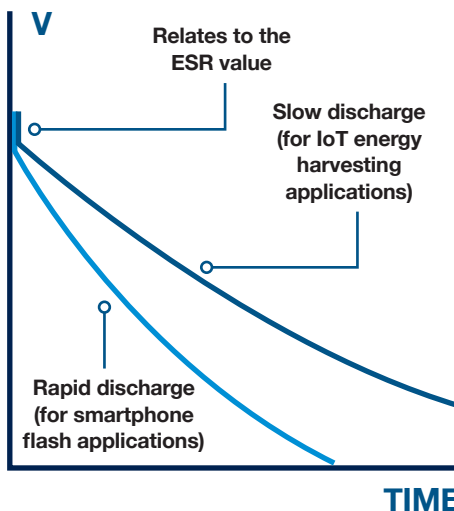
A capacitor's equivalent circuit takes into account the equivalent series resistance (ESR) and inductance (ESL), and the dielectric insulation resistance across the capacitance.



## MULTIPLIER FACTORS

3RD DIGIT	ORDER OF MAGNITUDE	EXAMPLE	CAPACITOR VALUE
0	1	470	47 pF
1	10	101	100 pF
2	100	222	2.2 nF
3	1,000	473	47 nF
4	10,000	224	220 nF/0.22 $\mu$ F
5	100,000	475	4.7 $\mu$ F

## SUPER CAPACITOR DISCHARGE PROFILES



## GLOBAL CAPACITOR MARKET

Current annual worth of \$20 billion in total (according to figures compiled by Lucintel)

It is estimated that nearly 5 trillion units were shipped in 2019 (according to Research & Markets)

## CAPACITOR CALCULATIONS

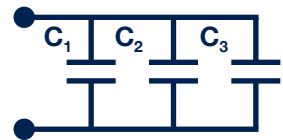
Series

$$\frac{1}{C_{\text{equivalent}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$



Parallel

$$C_{\text{equivalent}} = C_1 + C_2 + C_3$$



## EIA CAPACITOR TOLERANCES

CODE	TOLERANCE FIGURE
B	$\pm 0.1\%$
C	$\pm 0.25\%$
D	$\pm 0\%$
F	$\pm 1\%$
G	$\pm 2\%$
J	$\pm 5\%$
K	$\pm 10\%$
M	$\pm 20\%$
Y	$\pm 30\%$
Z	+80% -20%

## EIA CAPACITOR VOLTAGE CODES

CODE	VOLTAGE
0L	5.5 V
1A	10 V
1E	25 V
1H	50 V
2A	100 V
2D	200 V
2E	250 V
2G	400 V

## KEY CAPACITOR SELECTION PARAMETERS

- Capacitance
- Working Voltage
- Temperature Range Supported
- Leakage Current
- Equivalent Series Resistance (ESR)
- Tolerance Level
- Moisture Sensitivity